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OSPREY (*PANDION HALIAETUS*) POPULATIONS IN FORESTED AREAS OF NORTH AMERICA: CHANGES, THEIR CAUSES AND MANAGEMENT RECOMMENDATIONS

PETER J. EWINS[1]
Canadian Wildlife Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4 Canada

ABSTRACT.—Prior to European settlement of North America, Ospreys (*Pandion haliaetus*) bred throughout much of the continent in tall trees near productive shallow-water freshwater bodies. Ospreys need exposed locations to build their large nests, often in dead tops of older trees or snags in beaver swamps. Historical nest sites are poorly documented, but timber extraction and shoreline development have undoubtedly removed many preferred nest trees, likely causing population declines. Widespread use of persistent organochlorine pesticides after 1945 caused dramatic declines of breeding ospreys. Since bans on these toxins were imposed in the 1970s, most populations have increased at average rates up to 15% per year. Ospreys have adapted well to nesting on a wide range of artificial substrates, and in some areas up to 70% of nests are now on such structures. In many areas nowadays, up to 80% of tree nests occur within 500 m of open water. It is difficult to know what this figure was historically since more recent forest management often retains trees in shoreline buffer zones primarily for recreational and landscape reasons. Other important factors currently affecting breeding ospreys are: nest predation from raccoons (*Procyon lotor*) and Great Horned Owls (*Bubo virginianus*), degradation and loss of foraging areas, human disturbance and Bald Eagle (*Haliaeetus leucocephalus*) population increases. Forestry guidelines protecting Osprey habitat vary considerably among regions. Maintaining nonintervention buffer zones around Osprey nest trees results in substantial lost profit for foresters, yet the ecological basis for such zones is often unclear. Systematic studies of breeding Ospreys in relation to different forestry practices, and associated activities, are needed to provide more consistent, realistic and integrated conservation advice to resource managers.

KEY WORDS: *forestry; North America; Osprey; nest trees;* Pandion haliaetus.

Poblaciones de *Pandion haliaetus* en áreas de bosque en Norte América: cambios, sus causas y recomendaciones de administración

RESUMEN.—Antes de la colonización de Norte América, *Pandion haliaetus* se criaban por mucho del continente, en árboles de grande altura cerca de aguas de pesca productivas. *Pandion haliaetus* necesitan lugares desabrigados para construir sus nidos grandes. Con frecuencia en la copa de árboles maduros o también tocones en pantanos de castor. Sitios de nido históricamente están documentados de ser pobres, por extracciones de madera y el desarrolla a la orilla del agua, sin duda han quitado muchos árboles de nido preferidos, probablemente causando reducción de la población. Usos amplios de pesticidas de organoclorados (OC) después de 1945 causo reducciones dramáticas en la cria de *Pandion haliaetus.* Prohibición de estos tóxicos fueron imponados en los 1970s, y desde entonces la mayoría de población a subido a ritmo regular hasta 15% por año. *Pandion haliaetus* se han adaptado bien haciendo nidos que abarcan un campo amplio de soportes artificial, y en unos áreas hasta 70% de nidos están en tal estructuras. En muchas áreas hoy hasta 80% de los nidos en árbol ocurren dentro de 500 m al agua libre. Es difícil saber que fue la cantidad históricamente; mas reciente administración de bosque muchas veces retiene árboles dentro la orilla del agua en zonas de espacio primeramente para razones recreacional y aesthetico, a un extenso grande que en bosques mas lejos de la agua. Otros factores importantes actualmente afectando los *Pandion haliaetus* de cría son: depredador de nido, (la mayoría de mapaches, *Procyon lotor,* y búhos, *Bubo verginianus*), degradación y la perdición de áreas de forraje, molestia humana, y aumento en población de águilas *Haliaeetus leucocphalus.* Reglas del forestal protegiendo los *Pandion haliaetus* varia considerablemente entre regiones. Manteniendo zonas de no-intervencion de espacio alrededor de nidos de *Pandion haliaetus* resulta en suficiente ingresos perdidos para la industria de madera, y la razón ecológica para tal zonas es muchas veces poco claro. Estudios sistemáticos de *Pandion haliaetus* de cría en relación a diferente

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[1] Present address: World Wildlife Fund, 90 Eglinton Avenue East, Suite 504, Toronto, Ontario M4P 277 Canada.

costumbres del forestal, y actividades asociadas, son necesarias para proveer mas consistenes realistarias y consejos de conservación integrada para la administración de recurso.

[Traducción de Raúl De La Garza, Jr.]

Prior to the colonization of North America by Europeans, Ospreys (*Pandion haliaetus*) bred in trees throughout most of North America, though a few pairs nested on cliffs or on the ground on small islands (Poole 1989). The major changes in land-use patterns (notably forest clearance for agriculture and residential and industrial development) which have occurred since European settlement (Lawrie and Rahrer 1973, Caldwell 1978, Sly 1991) have undoubtedly affected the breeding distribution of Ospreys, but many other factors have also impacted these populations. In this paper, I review the documented population changes, highlighting cases for which the causes are reasonably well established. I then focus on Osprey nesting requirements, especially in relation to forestry practices and current timber management guidelines for Ospreys. I also suggest some key studies which should be done to better evaluate the sensitivity of Ospreys to different timber management regimes.

BACKGROUND

Ospreys are large (1.5–2 kg) raptors which eat almost exclusively fish, which they catch in water usually up to 2 m deep by diving in feet-first, either from a shoreline perch or from a hover or stoop from up to 40 m above the water (Poole 1989). They are monogamous, breed first when 3–4 yr old, have an 85–90% adult annual survival rate and can live for up to 25 yr. They have relatively long wings for their body mass and so are rather poor at maneuvering among trees. For this reason they require very open sites in which to nest so that birds can readily fly to and from the nest in any wind direction without getting tangled in branches. They build large stick nests which are added to each year. Thus, Ospreys favor nesting at the top of old, large trees, live or dead, with adequate strong support branches at the top and clear air space around the nest. Nest sites surrounded by water are usually preferred, since mammalian predators are thus deterred. Most Ospreys which breed in North America winter in northern South America or the Caribbean basin, but there are resident populations in Florida and California/Baja California (Poole and Agler 1987, Poole 1989, Ewins and Houston 1993).

Despite major reductions in both the extent and age of forests in North America over the past two centuries (Lawrie and Rahrer 1973, Caldwell 1978, Holla and Knowles 1988, Sly 1991), Ospreys persist as a relatively widespread and highly visible breeding species near to many waterways. Unlike some other raptor species, Ospreys have in many cases adapted remarkably well to living in close proximity to humans, and will nest readily and very successfully on artificial nest structures, especially when there is a tradition of this habit in an area (Postupalsky 1978, Ewins 1994, 1996). It has been estimated for the mid-1980s that North America supported about 18 000–20 000 pairs of breeding Ospreys or about 57–84% of the world population and that about two-thirds of these bred in Canada and Alaska (Poole 1989). Although Ospreys do breed in loose colonies in some areas, particularly near to rich food supplies in marine estuaries (Greene et al. 1983, Hagan 1986), the bulk of these birds breed as scattered, isolated pairs in relatively remote forests close to fishing areas in the numerous rivers and lakes of northern North America.

POPULATION CHANGES AND ASSOCIATED FACTORS

Ospreys have been relatively well studied over the past 30 yr in North America (Henny 1977, Poole 1989) and many factors are now known, or are suspected, to have influenced their populations since European settlement of the continent (Table 1).

Historical Populations (>100 years ago). Unlike Bald Eagle (*Haliaeetus leucocephalus*) nests, Osprey nests were seldom noted by early naturalists in North America, so it is often difficult to assess current occupancy of nesting areas occupied in the last century. However, given what we now know of the Osprey's nesting requirements, it is likely, given the massive reductions to the extent and mean age of forests, that prime nesting trees are very scarce in many former breeding areas. Impressions noted by Victorian naturalists lead us to suspect very large declines in some areas. For example, Beardslee and Mitchell (1965) cite a visit by the naturalist De Witt Clinton to the Niagara River in 1820: "In various places I have seen bald eagle, grey eagle and osprey *falco haliaetus*.... the immense quantities of fish which collect below the falls of Niagara.... draw together these birds, and I have never seen so many

Table 1. Main factors affecting North American Osprey populations.

Nest-site availability	—timber extraction —shoreline development —fur trade (beaver populations) —water level changes/reservoir creation —artificial nest structures
Food availability	—loss of foraging habitat to: —agriculture —shoreline development —nutrient changes —fish removal (chemical, over-fishing) —exotic species effects —lake acidification
Human activities	—egg collecting, taxidermy —persecution —disturbance at nest —environmental legislation and societal attitudes
Toxic chemicals	—persistent organochlorine pollutants —heavy metals (mercury)
Competition	—Bald Eagles (*Haliaeetus leucocephalus*) —intra-specific
Predators	—raccoon (*Procyon lotor*) —Great Horned Owl (*Bubo virginianus*)
Weather	—wind storms (nest loss) —cold and wet (chick starvation/hypothermia)
Wintering and Staging areas	—habitat loss —hunting/persecution —mercury (gold mining) —organochlorine pesticides

as appear to occupy this region." Today, eagles and Ospreys are rare sights along the entire Niagara River, even though there are still huge quantities of fish available below the falls, supporting very large concentrations of foraging gulls and fish-eating ducks in autumn. Very little undisturbed nesting, perching or roosting habitat now exists along the river banks, due to recreational access and residential development.

Along the Oregon-California border, a huge colony of 250–300 pairs of Osprey was recorded at Tule Lake in 1899 (Bailey 1902). The birds bred in two groves of large ponderosa pine (*Pinus ponderosa*) and junipers (*Juniperus occidentalis*) 6–10 km from the shallow, highly productive lake, because these were apparently the nearest stands of suitable nest trees to the lake (Henny 1988). So, even 100 yr ago it appears that the availability of preferred nest trees was influencing Osprey nesting distribution. After 1906, Tule Lake was drained to provide irrigation and new, fertile agricultural land; the area now supports a range of cash crops but only about 12 pairs of Ospreys (Henny 1988).

There are reasonable historical population estimates for Ospreys in six areas and biologists have been able to suggest factors associated strongly with the population change over the period (Table 2). In four of these cases, large declines were associated with combinations of factors such as persecution, egg/skin collection, wetland drainage for agriculture, loss of nesting trees to forestry or shoreline development and toxic effects of organochlorine pesticides. The provision of artificial nesting structures seems to have offset the effects of other factors and maintained reasonably stable populations in parts of Maryland and Ontario (Reese 1969, Ewins 1996).

Changes Since the 1930s. The simple chemical process of adding a chlorine atom to a benzene molecule probably had a greater effect on Osprey populations than all other factors combined. From the mid-1940s to the early-1970s, organochlorine pesticides were used widely and effectively in North America and these molecules proved to be extremely persistent environmental contaminants. Ospreys, like other raptors at the top of food webs, bioaccu-

Table 2. Historical records of Osprey population changes, and factors implicated by authors.

AREA	NUMBERS/YEAR	FACTORS IMPLICATED
Gardiner's I., NY	300 prs./1850s 300 prs./1940 100 prs./1960 31 prs./1975	Protection from persecution Organochlorine pesticides
Seven Mile Beach, NJ	100 prs./1884 <25 prs./1890 30 prs./1927	Egg collecting and shooting
Queen Annes Co., MD	32 prs./1892 31 prs./1968	Forestry, artificial nest structures
Georgian Bay, Lake Huron, ONT	"generally distributed"/1890s 0/1940s-72 43 prs./1993	Forestry, shoreline development, organochlorine pesticides, artificial nest structures
Tule Lake/Klamath, OR	250–300 prs./1899 ca. 12 prs./1976	Drainage, agriculture
Eagle Lake, CA	>2 prs./1905 30–35+ prs./1925 23 prs./1975	Water level changes providing snags

mulated substantial concentrations of these lipophilic compounds from their diet. Most notable was DDT and its more stable metabolite DDE, which impaired shell gland function and led to severe thinning of eggshells and resultant reproductive failures as the eggs broke during incubation (Ames 1966, Cooke 1973). The cyclodiene dieldrin was also highly toxic and may well have increased mortality rates of Ospreys. By the 1960s, naturalists noticed numerous empty Osprey nests, broken eggs, large population decreases (Ames and Mersereau 1964, Ames 1966, Petersen 1969) and even local extirpations (Ewins et al. 1996). By the early to mid-1970s the use of organochlorine pesticides and polychlorinated biphenyls (PCBs) had been banned throughout North America.

Table 3. Population trends for North American Ospreys since the 1930s. Means expressed as percentage change per annum.

LOCATION	PERIOD	MEAN % PER ANNUM
Migration look-outs		
Northeast U.S.A.	1972–87	+8.9
Hawk Mt., PA	1934–86	+0.1
Duluth, MN	1974–89	+5.5
Grimsby, ONT	1975–90	+6.8
Western U.S.A.	1983–91	+7.0
Breeding areas		
Wisconsin	1974–90	+8.9
Northeast U.S.A.	1975–87	+10.0
Upper NY	1976–90	+6.8
St. Marys R., MI	1975–93	+15.4
Michigan	1976–89	+6.0
L. Huron, ONT	1975–94	+13.2
Oregon	1976–93	+10.5
California	1981–93	+9.4

Increases in breeding Osprey populations were noted in most parts of North America from the mid-1970s (Table 3, Fig. 1), associated with declining organochlorine contaminant residue levels in eggs and increases in eggshell thickness towards pre-DDT values (Henny et al. 1977, Spitzer et al. 1978, Wiemeyer et al. 1987, 1988, Ewins et al. 1996). The mean rates of population recovery across the continent (6–15% per annum) have been remarkably similar in different areas (Table 3), suggesting that the organochlorine pesticide effects were widespread and relatively uniform. The long-term monitoring at Hawk Mountain migration station in Pennsylvania started just before the introduction of these pesticides, so the 50-yr population trend includes many of the pesticide-use years. Extensive and intensive state- and province-wide Osprey surveys over the past 20 yr have shown similar recovery trends in reproductive output.

Some Cause-effect Examples. The availability of suitable nest sites appears frequently to limit local breeding populations. The creation of reservoirs for

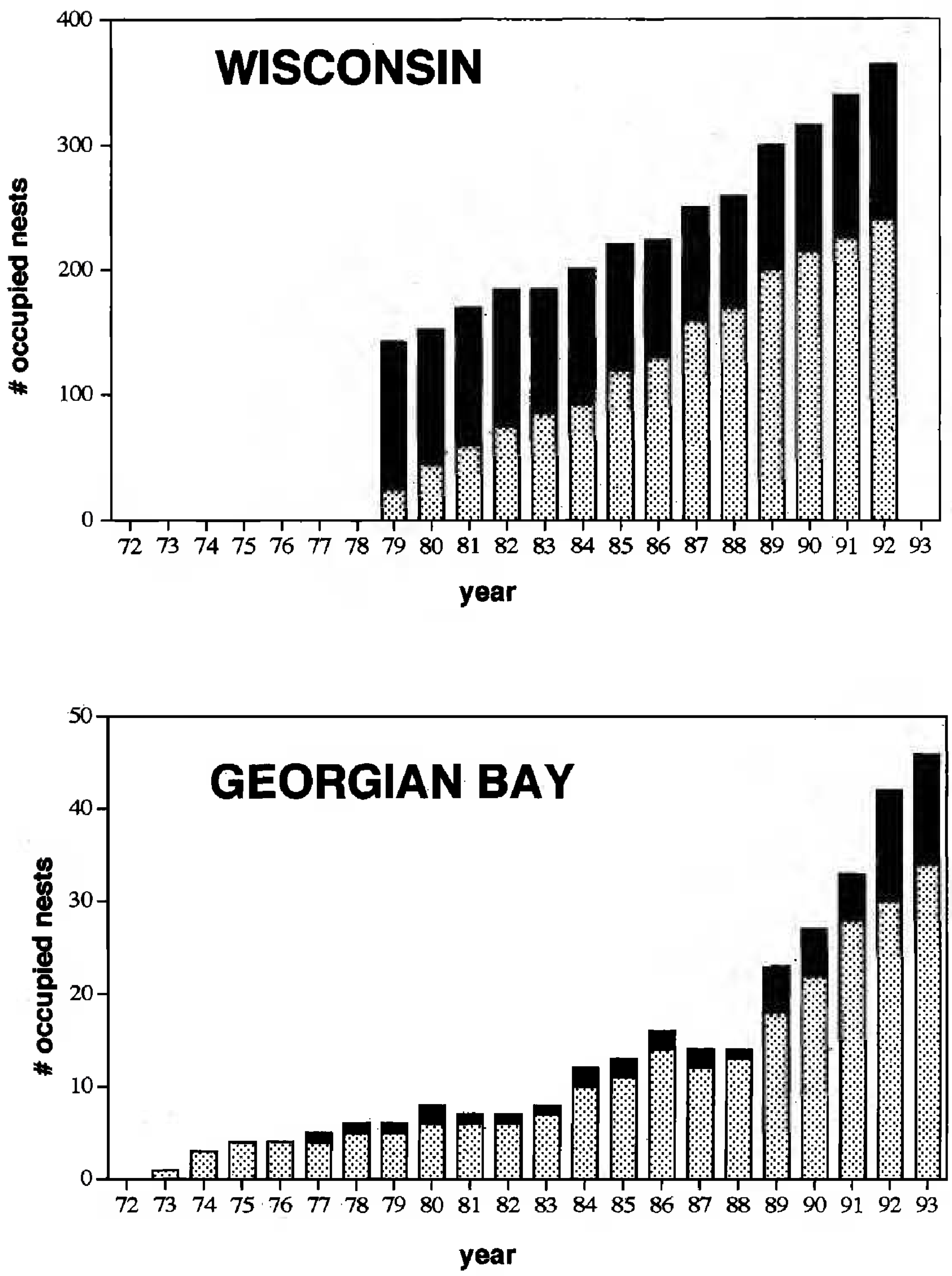

Figure 1. Changes in breeding populations of Ospreys since early 1970s in Wisconsin and Georgian Bay (Lakes Huron and Ontario), at artificial nest-platforms (stippled) and other (solid shading) sites. Most "other" sites were in trees. Wisconsin data are from Gieck et al. (1992).

hydroelectric power generation, irrigation of agricultural land and raising of water levels for navigation or other purposes, has often provided quality nest sites for Ospreys by flooding trees. At Eagle Lake, California, population increases earlier this century were attributed to raised water levels providing prime nest sites, but subsequent steady decay of these flooded trees had reduced the nesting population by the 1970s (Table 2). Similar phenomena have been observed in the Great Lakes basin, at Ogoki Reservoir (Postupalsky 1971) and in the Kawartha Lakes and in Montana (Mace et al. 1987).

Human attitudes towards raptors and general environmental issues have changed markedly in recent decades. Protective legislation is now available for many habitats and species and people often want to take positive actions to assist with restoration of degraded ecosystems. In many areas, particularly those close to centers of human population, customized artificial nest structures are occupied readily by Ospreys (Poole 1989, Gieck et al. 1992, Ewins 1994, 1996, Ewins et al. 1995), and these initiatives have greatly assisted population recoveries post-DDT. In some areas, up to 70% of occupied Osprey nests now occur on artificial support structures. For example, in Wisconsin and Ontario, much of the recent population increase has been due to increases in the number of artificial sites available and not the number of tree sites occupied (Fig. 1). Hydro poles, high-voltage transmission towers, navigation aids and a wide range of other structures are also used by Ospreys, enabling them to reoccupy areas in which preferred large trees and snags are in short supply close to good foraging areas (Reese 1970, Westall 1983, Poole 1985, Martin et al. 1986).

Reductions in fish populations and their predators in northern, base-poor lakes and rivers have been associated with acidification from precipitation (Almer et al. 1974, Mason and Seip 1985, Bevanger and Ålbu 1986, Schindler et al. 1989, Gill 1993). Although there are few North American Osprey lake acidification studies, reduced productivity and breeding population density of Swedish Ospreys has been noted in lakes experiencing high degrees of acidification (Eriksson et al. 1983, Eriksson 1986). An increased availability of naturally-occurring metals (such as mercury and aluminum) in highly acidified lakes may also prove to be a significant toxicological factor for Ospreys (Nyholm 1981, Poole 1989, Gill 1993, Scheuhammer and Blancher 1994).

The influence of human disturbance of Ospreys at their nest seems to vary according to whether the birds are already used to human presence or not, whether the disturbance is regular from the onset of the nesting season or if it commences during a sensitive stage such as the incubation or small chick stage (Swenson 1979, Poole 1981, Van Daele and Van Daele 1982, Levenson and Koplin 1984). In many areas nowadays Ospreys nest very successfully within 100 m of cottages, roads, railways, boating channels etc., and it is likely that birds recruiting to such sites have been raised in similar situations. Contrastingly, reduced breeding success is often experienced by birds disturbed after nesting has begun, particularly in remote areas or where little or no human disturbance has occurred earlier in the season (Swenson 1979, Levenson and Koplin 1984, Poole 1989). There is little evidence that propeller or jet fixed-wing or rotor-winged aircraft flying low over Osprey nests, even in remote areas, cause marked reductions in breeding output or site occupation in subsequent years (Carrier and Melquist 1976).

Bald Eagles are generally more sensitive to human disturbance than are Ospreys, particularly in the early spring, but in more remote areas Ospreys are excluded from suitable nest trees and foraging areas by the eagles (Ogden 1975, Gerard et al. 1976). As Bald Eagles continue to slowly recover from the effects of DDT and other organochlorine contaminants, they are likely to move into former nesting areas which already support Ospreys, which will result in local declines in Osprey numbers or shifts to suboptimal nesting locations, further away from the foraging areas. In various parts of the Great Lakes basin, this phenomenon is already well-established.

TREES AND OSPREYS

Ospreys will nest in a wide range of tree species, heights and ages. I agree with Henny (1986) that historically most Ospreys probably nested "... in the tops of snags or trees with dead tops, although live trees were also used." The most important nest-site selection criteria today seem to be: clear aerial access to the nest, at least one strong side branch to support the heavy nest, proximity to water/inaccessibility to mammalian predators, avoidance of Bald Eagle territories and nearby elevated perch. Islands are particularly attractive to Ospreys, largely due to proximity to foraging areas and reduced mammal populations, and at least 50% of the world's ospreys are thought to breed on islands (Poole 1989). Of equal importance as the characteristics of occupied nest trees is the surrounding stand. In forests, Ospreys usually build their nests above the surrounding canopy, whether it is 15 m or 50 m above ground level. As a result, they tend to select older trees and often dead trees or those with dead, flat or blown-out tops. For example, of 85 occupied nest trees I documented in various parts of Ontario between 1990–95, 80% were conifers (mostly white pine, *Pinus strobus*) and 20% were deciduous species (mostly white birch *Betula* spp., with some poplars *Populus* spp.). Live trees supported 47% of the nests, flat-topped or dead-topped conifers supported 12% and the remaining 41% of nests were in totally dead trees, often in swamps created originally by beaver activity.

Some species have more open, irregular crown architecture than others, making them more suited to Osprey nests. For example, in Minnesota's Superior National Forest, 77% of 301 Osprey nests over 31 yr were in super canopy white pine, even though this species represented less than 0.5% of trees with dbh >10 cm (Rogers and Lindquist 1993). In Oregon's Deschutes National Forest, large ponderosa pine are the preferred nest tree (90% of nestings), with mean tree height 35 m, mean dbh 95 cm and 30% of nests are in live trees, 21% of dead-topped trees and 49% on dead snags (Gerdes pers. comm.). Dead-topped tall trees are often more common in areas infected with insect pests, blister rusts (Eckstein pers. comm.) or in areas with heavy winter icing or wind storms which snap off the growing top.

As timber has been removed from North American forests, so the mean age of forests has declined. The mean height of trees available to nesting Ospreys has decreased, as presumably has the number of trees with sufficiently strong side branches at the top to support Osprey nests over a number of years. The lowest rates of nest collapse from blowdown or branch breakage (% nests lost per year) are in the north, likely reflecting tree age/suitability: northwestern Ontario 5% (Grier et al. 1977), southcentral Ontario 12% (Ewins 1996), Montana 10–15% (Grover 1983), New York 30–40% (Poole 1984), Maryland 10% (Reese 1977), Florida 50–70% (Poole 1984), California 30% and Mexico 18–44% (Airola and Shubert 1981). Various studies have found that reproductive output from tree nests is often lower than at nests on artificial platforms (Reese 1977, Postupalsky 1978, Van Daele and Van Daele 1982, Westall 1983, Poole 1989), but when hydro poles are considered separately from customized nest platforms, these differences are less obvious, especially in areas with large trees (Ewins 1996, Henny and Kaiser 1996). In general, with populations still increasing at rates averaging up to 15% per annum, there is little evidence for population-level impairment of reproduction due to shortage of quality nest support structures.

Surveys of Osprey breeding distribution over the past 25 yr have usually found most tree nests to be close to water. For example, 55% of nests in northern California were within 1 km of water and all were within 10 km (Garber 1972), and in Oregon 83% of 78 nests in 1978 were within 1 km and all were within 2 km of water (Henny et al. 1978). In the Deschutes National Forest in Oregon, successful nests in large ponderosa pines >200 yr old in 1970–71 were not significantly closer to water than unsuccessful nests ($\bar{x}$ = 1.2, SD = 1.6 km, range = 0.1–4.8 km for successful nests; $\bar{x}$ = 1.6, SD = 1.4 km, range = 0.1–4.8 for unsuccessful nests; Lind 1976). In Ontario during the 1990s, 93% of 179 tree nests were within 500 m of water; the median distance to water for tree nests was 10 m, but only 4 m for nests on artificial platforms (Fig. 2).

To what extent does this evidence indicate that Ospreys prefer to nest close to water? Clearly, Ospreys will seek to minimize energy expenditure wherever possible and nest close to food resources.

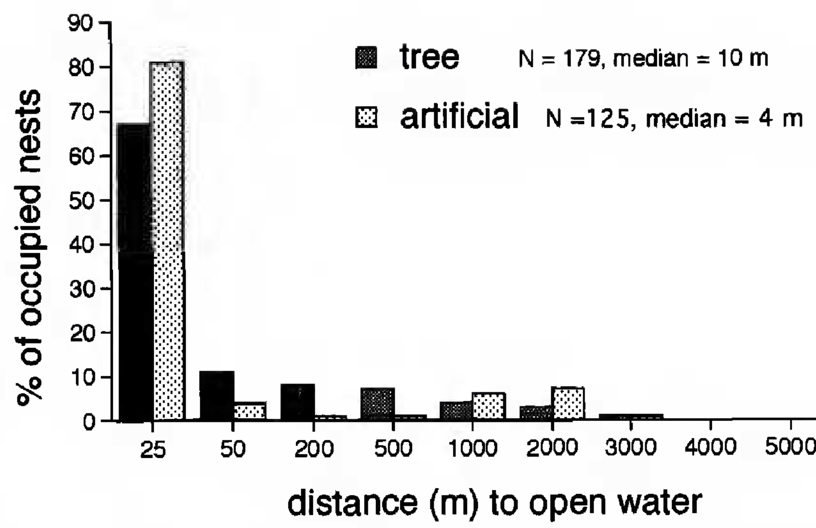

Figure 2. Frequency distribution for 304 occupied Osprey nests in Ontario of distance from open water (river, or lake >2 ha), 1990–95.

But, this must be balanced against nest stability and risk of predation. Selective and clear-cut logging in many areas has usually been more intensive further away from water courses, due in part to landscape considerations and the need to provide visual screens for recreational boaters and canoeists. Thus, the availability of potentially suitable large trees for nesting Ospreys may not be comparable at differing distances from the foraging areas. Perhaps there were, historically, many more suitable large trees for ospreys further away from the water. A clue is provided from studies along the Atlantic coast. There, some Ospreys regularly nest in trees 14 km or more from the main fishing areas due to a shortage of suitable nest sites (Greene et al. 1983, Hagan 1986). In New Brunswick, Ospreys commonly nest on hydro poles, and for 151 nests in 1993, the median distance to water was 1.0 km, but 45% of nests occurred from 1–5 km from water (Stocek pers. comm.). This suggests that provided suitable tall nest support structures are available, a greater proportion of Ospreys will breed further from the foraging areas than is found in areas where suitable tree sites are in short supply. Thus, I suspect that, historically, considerable numbers of Ospreys bred well away from the water in most of North America and especially in areas where Bald Eagles occupied the prime super canopy or large snag nesting trees in water's-edge territories (Ospreys generally avoid nesting near Bald Eagles).

Nesting immediately over water, such as on a stump, flooded tree or navigation aid, presumably reduces the risk of predation at the nest, and so would be expected in preference to tree nesting on land. There is little firm evidence for this, but on Chesapeake Bay, navigation aids, duck blinds and nesting platforms over water seem to have been occupied even though large trees were apparently still available along the river banks (Reese 1969). However, predation by raccoons (*Procyon lotor*) and Great Horned Owls (*Bubo virginianus*) does occur at over-water nests (Poole 1989) so no generalizations can yet be made about the selective advantage to nesting in these different situations.

There is remarkably little published or unpublished information on Osprey nest trees and reproductive outcomes in areas subjected to timber extraction. Collating data from many individuals across North America, I reached the conclusions that there is an urgent need for a systematic field study and that no firm generalizations can be made. In some cases Ospreys continued to nest successfully in an isolated tall tree or snag left after clear-cutting, in others Ospreys have actually moved to an isolated tree within a clear-cut and in other cases Ospreys have abandoned a nest during logging activities, or road construction, or have abandoned the entire area after a nest tree was removed and no suitable alternatives seemed to be available nearby.

In California, 15 Osprey nests within 500 m of logging roads suffered significantly reduced breeding output if logging traffic use of roads commenced once Ospreys had already initiated breeding (Levenson and Koplin 1984). This study rejected the conclusion of Melo (1975), which was based upon a single nest observation, that logging activities could safely continue during the Osprey breeding season to within 30–35 m of the nest.

It is likely, though not quantified, that the large changes in beaver (*Castor canadensis*) populations over the past two centuries have greatly reduced the availability of snag trees over water, often preferred by nesting Ospreys. Intensive trapping led to severe depletion of beaver populations at various stages and regions over the past two centuries (Newman 1985, Dunstone 1993). In many northern parts of North America, Ospreys breed in snags in swamps formed as a result of beaver activity. Thus, this human trapping pressure almost certainly greatly reduced the number of suitable snags available for nesting Ospreys.

CURRENT FOREST-MANAGEMENT GUIDELINES FOR OSPREYS

With populations of Osprey and other raptor species at record low levels in many areas during the 1960s, due largely to the effects of organochlorine pesticide accumulation, considerable attention turned towards restoration measures. Restrictions on the use of DDT and dieldrin were finally introduced in the early 1970s and many agencies then focused on habitat management for Ospreys. The first Osprey Management Area was designated at the Crane Prairie Reservoir in Oregon's Deschutes National Forest (Roberts 1969) and the management plan formed the basis for subsequent forest-management guidelines and recovery plans for Ospreys across the continent. These management guidelines vary considerably among areas, most notably in the distances they recommend for the various types of buffer or exclusion zones, but also in the suite of exclusions and various proactive conservation measures (Roberts 1969, Kahl 1972, Garber et al. 1974, Penak 1983, Gieck 1986, Henny 1986, Nova Scotia Dept. Lands and Forests 1987, U.S. Forest Service 1974, 1991).

Nesting Habitat. *Absolute buffer zone*—within a 40–200 m radius of an occupied nest tree, access is restricted year-round and limited to activities benefiting the nest site (e.g., nest support modification, collection of scientific data, tree safety pruning).

Seasonal buffer zone—within 100–800 m radius of an occupied nest, or up to 600 m beyond the periphery of the absolute buffer zone and for the duration of the breeding season (usually 1 April to 31 August), certain activities are restricted or banned. These include logging, road or pipeline construction, mining, peat extraction and some forms of recreation. Outside this breeding period, recreational activities and controlled tree harvesting and planting is permitted. Within clear-cuts, some small- and medium-sized trees should be retained in clumps, as well as some large snags. Some plans advise retaining >4 flat-topped tall dominant trees or snags, or all snags >36 cm dbh (U.S. Forest Service 1974), or even to remove the tops from some live large trees to create more suitable nesting trees.

Riparian/lacustrine buffer zone—for distances of 70–350 m back from the water's edge, the guidelines vary from no cutting, to retention of up to 5 snags and 5 clumps of tall trees, or the preservation of clumps of large living or dead trees, or >10 trees/ha. In addition, Kahl (1972) and Garber et al. (1974) recommend retention of all broken-top and other suitable nest trees up to 3.5 km beyond this 350 m buffer zone.

Foraging Habitat. Restrictions apply to development which could degrade shallow-water fish habitat. Recommended bans on the use of chemical control of undesirable, nongame fish species. Water levels should be maintained so as to allow Ospreys access to fish.

General Guidelines. Early consultation with the area wildlife biologist is stressed by most plans and their approval required prior to any timber sale. Suitable training for field foresters in wildlife identification and the forest-management guidelines is recommended. Protective measures may be lifted after prolonged inactivity of a nest tree. The need for ongoing monitoring is stressed. Some plans recommend "guarding against the effects of pesticide sprays" (Penak 1983), which presumably refers to the persistent, yet highly effective and toxic organochlorine pesticides. Proactive measures are stressed especially by the early management plans in California, where dead and live trees were modified to provide stable nest supports for Ospreys, wherever human safety was not compromised.

Thus, there is wide variation in forest-management guidelines for Ospreys across North America. To a large extent this reflects the uncertainty in the response of Ospreys at the population level to different types of forest management and our lack of understanding of basic components of Osprey ecology in forested areas. This has naturally led to some confusion and questioning among resource managers. For example, Ontario's new Forest Planning Manual has 39 complex guidelines of this type, which many foresters find much too complex and ignore (Euler pers. comm.). Hence, although the Ontario guidelines for forest management in the vicinity of Osprey nests are relatively stringent (Penak 1983), we find that adherence is largely dependent upon the inclinations of individuals on the ground, both foresters and local wildlife biologists.

An interesting economic concern has been posed by Opper (1988). Based on 1980s mean timber values and forest yield parameters in Ontario pine forests, he has calculated that adherence to the provincial forest-management guidelines near an Osprey nest "preempts about 465 units of wood, which would produce approximately 280 tons of pulp......thus costing about $CAN 168,000 to protect a single Osprey nest." While accepting the principle of integrated and sustainable forest and wildlife resource management, Opper understandably questions "... the scientific or biological rationale upon which (such) wildlife prescriptions are made." These questions highlight an urgent need for sound biological data to justify particular management guidelines for Ospreys, since we currently have only scattered and anecdotal evidence. This suggests that Ospreys at either the individual or population level exhibit variable tolerance to forest-management activities and associated disturbance of different types.

The protection of mature, over-mature and deadwood timber in riparian zones, or as isolated trees or small clumps in clear-cuts clearly provides Ospreys and Bald Eagles with suitable nest trees. But one might expect elevated nest predation rates in such strips/corridors, due to predators moving along such corridors or between clumps of trees. In clear-cut areas, retention of isolated tall trees or snags generally increases the exposure to wind and the likelihood of trees blowing down. Thus, it is important to retain a number of alternative sites/clumps and ideally to conserve some younger trees which would, in time, replace the suitable nest trees at the time of timber extraction.

Finally, we should remember that the decisions regarding conservation of trees for nesting Ospreys must be made in an ecosystem context. Many other important components of the forest wildlife community will benefit by retaining groups of larger and dead trees in any clear-cut areas and these decisions should clearly be made on an ecosystemic and long-term basis, not just for one species of raptor on a short-term basis.

RECOMMENDATIONS

There is a clear need for a systematic study of nesting Ospreys in relation to different forest-management activities. This need is as much from a forestry-economic perspective as from an Osprey-conservation angle. Such a study could well be done cooperatively with the forest industry and a suitable student/university/conservation or government agency. The ultimate objective would be to provide an objective assessment of the responses of nesting Ospreys to factors associated with timber extraction, both at an individual and population level and over the course of a few years (not just 1–2 yr). For example, the study should compare breeding productivity and nest occupancy rates over 3–5 yr at sites with different intensities and types of human disturbance, with different sizes and ages of clear-cuts, at various distances from water and with different numbers of alternative nest trees within the vicinity. Nest predation rates and tree stability in narrow riparian corridors and at isolated clumps of trees should also be assessed. Such a study would require large study areas, but foresters are operating at this scale already. The benefits to the industry would be substantial if it were found that Osprey populations can generally adapt well to logging activities.

The final recommendations in relation to Ospreys should then be integrated with the results from any studies of other wildlife species with specific niche requirements (e.g., other raptors, cavity-nesting birds, mammals), to produce general guidelines for sustainable forestry which would accommodate the needs of a wide range of wildlife species and not just one or two top predators. If in doubt, I would strongly recommend erring on the cautious side by retaining more dead snags, larger clumps of dominant trees and broader nonintervention riparian strips.

GENERAL CONCLUSIONS

North American Osprey breeding populations in the 1980s–1990s appear relatively healthy and are still increasing in most areas, following the dramatic declines caused by the effects of organochlorine contaminants during the 1950s–1970s. Many factors are known or suspected to impact Osprey populations and their breeding productivity and the relative importance of these varies considerably across the continent. Prior to European colonization of North America, most Ospreys probably bred at the top of large trees, but as forests were cleared and the mean age of forests declined considerably, Ospreys have adapted to nesting on artificial structures, often over water. In many areas, they have also habituated to nesting in close proximity to humans. Artificial nesting structures are not a viable long-term alternative to natural, tall tree support structures for Osprey nests.

Many of the present guidelines for forest management in the vicinity of Osprey nests stem from advice used 15–25 yr ago, when Ospreys were classified as threatened or endangered in many parts of the range. In light of the dramatic population recovery since the mid-1970s, a review of these guidelines is appropriate. Forest-management plans should ensure, in an ecosystemic context, that sufficient large live trees and standing deadwood snags are retained after timber extraction to provide nesting Ospreys with a number of alternative nest trees close to shallow-water foraging areas. In relation to nest-site requirements, Ospreys are relatively adaptable, compared to many other raptors and other animals of North American forests. The precise nature and extent of this adaptability needs to be confirmed and properly quantified for Ospreys nesting in commercial forests and more consistent guidelines adopted across the continent once this type of study has been completed. Current guidelines for Ospreys in some forest-management plans may be difficult to justify based on the needs of Ospreys, at least at the population level. However, retaining large residuals of mature trees benefits many other species in forest ecosystems, not only Ospreys, so we clearly need to adopt an ecosystem approach. Forest-management guidelines for wildlife should not restrict timber harvesting or recreational use of forests unnecessarily, yet they should ensure that the needs of the most sensitive components of the forest ecosystem are provided for, even if they are not so highly visible or adaptive as a top predatory species like the Osprey.

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